THE FOUCAULT EXPERIMENT.

By J. T. LOVEWELL, Topeka.

AMONG the scientific achievements of the French philosopher, Foucault, there is none that made him so widely known as the pendulum experiment, whereby he rendered visible the rotation of the earth. This experiment was published in 1851 and was at once repeated by many scientific men in Europe and America. Arago performed it at the University of Paris, and it was exhibited in the Pantheon, with a pendulum 220 feet long.

In our own country it was set up in Bunker Hill monument, in the capitol, at Washington, and in various state capitols.

Use was made of these lofty edifices, which had requisite solidity, and allowed a longer pendulum than can often be installed in smaller structures. While long pendulums are desirable in this experiment, they are by no means essential to show the main fact of the rotation of the earth. Foucault's original experiment was made with a pendulum only six and one-half feet long, and with this he demonstrated the earth's rotation with entire success.

The idea of Foucault's pendulum is involved in the law of inertia, and it had occurred to others long before his time, but he was the first to bring it to a demonstration. The vibration is caused by force of gravity, always directed toward the center of the earth, and is entirely independent of the motion of the point of suspension. The absolute motion of the pendulum in space is very complicated, and involves both the annual and diurnal rotations of the earth, but we are here concerned only with the relative change in direction, with lines on the earth, and this is, as we shall see, at the poles, fifteen degrees per hour. By considering the pendulum mounted on a prolongation of the earth's axis, its plane of oscillation will cut across the meridians and will make a complete circuit in twenty-four hours.

At the north pole this apparent rotation would be like the hands of a watch, from left to right, while at the south pole this motion would appear in the contrary direction. At the equator there would be no rotation, while in other latitudes the motion would be the rate at the poles multiplied by the sine of the latitude. This may be shown in various ways by mathematical demonstration, and may be simply illustrated by the use of a globe, and drawing a line in the plane of oscillation, and comparing its direction with

various meridians. The globe will show the apparent revolution of the plane of inertia, and the time will be twenty-four hours divided by sine of latitude.

The first attempt by the author of this paper to make an accurate Foucault pendulum was at Washburn College, some six or seven years ago, where one of the ventilating shafts in what is now called Rice hall was used, and where one could get a length of more than fifty feet, but the arc of vibration could be not more than one and one-half feet. The greatest difficulty was the narrow space for making adjustments, and yet some results were shown to this Academy which appeared to be of interest. The plan was adopted of marking the oscillations with a needle on a plate of smoked glass, and then blue-prints were made of these pendulum markings for the first time in experiments with the Foucault pendulum. One of these prints, made six or seven years ago, is still preserved.

In the state-house, near the Academy rooms, is a space which seems peculiarly well suited to the Foucault experiment. It is in one of the light shafts, and the Executive Council were ready to grant the use of this waste space for these experiments, provided no expense to the state was incurred. The light shaft in question is a space of about ten by fifteen feet, and extends from the first floor to the roof, where it is surmounted by a skylight resting on a system of iron trusses and rafters, and the rafters are covered with sheets of plate roofing glass.

The pendulum wire passes through a hole drilled through this glass, and then through a steel plate by a hole just large enough to admit a No. 15 piano wire. The wire is wound on an iron cylinder an inch in diameter, with a crank and a rachet wheel, furnished with a dog to hold it in any desired position. The length of this pendulum as determined by its rate of oscillation is about seventy-three feet, and the bob is a cylinder of lead terminating with a cone at the bottom, and weighs sixty-eight pounds. The lead is cast around a stout brass tube and is turned on a lathe to a symmetrical form. The brass tube coming through the lower extremity of the bob has inserted in it three concentric glass tubes, the inner one being just large enough to admit easily a No. 1 sewing needle. This smaller tube is narrowed by heating until it is able to let the point of the needle pass through one-fourth of an inch. It is now free to play up and down through this distance, and to trace on the smoked glass below the course of the pendulum through its circular arc. The time of a double oscillation is very close to three and one-half seconds. To start the pendulum, it is pulled to one

side by a small cord attached to a staple fixed as near as could be estimated to its center of oscillation. The thread is fastened to the wall and the bob, thus displaced, is left until it comes entirely to rest. Then the string is burned off and without any lateral push the pendulum falls, simply under the impulse of gravity. The smoked-glass plate rests on a platform, which has a mechanism for raising and lowering with parallel motion, and permits the tracing needle to follow the plate two or three feet or any other desired distance.

There are several disturbing agencies which prevent the pendulum from tracing a straight line as it swings, and make it move in an ellipse of greater or lesser eccentricity. The most troublesome of these is the action of air currents, which cannot be wholly avoided. Even if the room were tightly closed, the variations of temperature and movements of the observer would cause fluctuations of air which would sensibly affect the pendulum.

Another difficulty is the elasticity of the suspending wire. This is bought in coils and it is difficult so to straigthen it that it will not tend to fall in spiral twists which are not equally elastic in every direction. Then there is lack of perfect rigidity in the point of suspension, which must also fail to represent a true mathematical point. There is no better plan for suspension yet devised than the method described above, of allowing the wire to pass tightly through a hole in a metal plate.

The author once thought it important to provide a plan for rotation of the wire, but became convinced that this refinement was entirely useless. Aside from these mechanical imperfections there is another and an insurmountable object, which prevents the pendulum from swinging backward and forward in the same path. When the pendulum is drawn aside at its starting it must partake of the rotary motion of the earth, and this, combined with the gravitational force, is sure to give it an elliptical course. In securing the graphical representation of these vibrations, there is still another disturbing element, for our needle-point can seldom be brought into the true axis of the pendulum. Where this needle-point is not in the true axis its friction against the smoked glass tends to give the bob a rotary oscillation, and, in the experiments hitherto made, this rotary oscillation is quite in evidence. It gives the outside edge of our blue-print a curious wavy border, and the time of these oscillations is many fold greater than the regular swings of the pendulum. The impelling force is here the torsional elasticity of the wire, which, acting on the heavy weight, gives a

true harmonic motion, and the slowest hitherto observed by the author of this paper. It would require a pendulum many hundred feet long to secure this rate of vibration. There is still another oscillatory movement to be observed in our pendulum, and this is a vertical oscillation, an up-and-down movement, due to the longitudinal elasticity of the wire. This movement is much more frequent than the former and has no influence on the Foucault experiment.

It will be seen from inspection of the graphs that the minor axis of the elliptical oscillation is very small, not more than one-tenth of an inch in a swing of four feet, and the air currents are probably responsible for most of this. The time is so recent since the installation of the apparatus that but few experiments have as yet been made, but they encourage us to expect results as good as any hitherto obtained by other observers.

There is a thought, too, that this pendulum may record seismic motions, which will certainly be of interest.

The pendulum is where any visitor to the state-house can see it, and there is a certain impressiveness in the sweep of the heavy weight to and fro so steadily. When starting with long vibrations, and watched for some time, close observers will notice that the period of oscillation is sensibly shorter as the arc becomes less. The old Florentine, Galileo, was mistaken in thinking the swinging chandelier performed its vibrations in equal times, whether through long or short swings, but he was near enough right to instal the pendulum as our most perfect measurer of time. Starting with an arc of ten feet, this pendulum will continue to swing as much as fourteen hours when it does no work in tracing the smoked glass. After a few hours its path cuts across its first direction with an angle that shows the time of a complete rotation at this latitude to be more than forty hours. The cuts herewith given exhibit the deviation at different intervals, but experiment has not been made sufficiently as yet to secure accurate numerical results. These may be given in a future paper.

It was intended to exhibit the tracings of this pendulum by half-tone engravings taken from the smoked-glass blue-prints, but they will not do for making printing plates, and time has not been allowed for securing them in other ways. For the finest results these experiments must be made when the air is still, because the wind gives a tremulous motion to the state-house roof which disturbs the pendulum.